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LONG RANGE DIFFERENTIAL GPS AND THE CONCEPTS OF CHINESE PLANS TO ESTABLISH BROAD AREA NETWORKS

Lu Guohua Liu Yanli

Translation of "Yuan Jyu Li GPS Cha Fen He Wo Guo Guang Yu Wang Jian She Fang An She Xiang"; Telemetry and Remote Control, No.4, Vol.16, August 1995, pp 1-11

ABSTRACT This article describes the general status of radio navigation and positioning systems. Stress is laid on introducing GPS global navigation systems, putting forward the use of methods associated with differential GPS in order to raise positioning precisions and carry out long range differential tests from Xian to Luoyang and Jinxi. Recommendations are made to set up a Chinese differential GPS network.

KEY WORDS GPS differential GPS pseudorange User station Datum station

I GENERAL OUTLINE

Before radio navigation equipment came out, people made use of ground markers on land or islands as well as the positions of celestial bodies in the heavens in order to precisely determine the positions of vessels. Such navigation and positioning equipment as the sextant, the magnetic compass, the log, inertial navigation systems, and so on, appeared. However, this equipment was subject to the influences of aerial visibility and magnetic fields. Moreover, measurement precisions were not too high in all cases.

1.1 Radio Navigation Systems

Radio systems using the land as their basis already have a history of over ten years. It is possible to use them in order to supply navigation data and position lines. Domestically and internationally, frequency distribution plans have already been set out in order to protect certain frequency bands associated with this type of use. At the present time, the radio navigation and positioning systems which are in use are many and varied. For example--making a classification on the basis of position line configurations--they can be divided into the following.

(1) Range finding systems--for example, radio range finders, also called round circle systems.
(2) Range finding differential systems--also called hyperbolic systems such as the Changhe No.2 (Luolan C), Taika, Omega system, and so on.
(3) Angular measurement systems--for example, very high

frequency omnidirectional beacon stations.

(4) Range finding and angular measurement systems--for example, TACAN systems.

The advantages of the radio systems described above are very numerous. They are not influenced by weather. They possess comparatively high navigation and positioning precisions. There are a number of radio systems which are also effective to relatively long ranges--even to the point of being capable of operating within global ranges. They each possess different characteristics, having special applications. Their common drawback is that, following along with increases in effective ranges, precisions constantly go down. In the 1970's, there were developed satellite borne systems of satellite navigation and positioning equipment, including the TRANSIT satellite navigation system as well as the GPS global positioning system, and so on. After GPS was introduced into service, part of the radio navigation and positioning equipment in use at the present time could then be eliminated. This is because the services they provided can also be provided by GPS. Due to the fact that the TRANSIT system is on the verge of being shut down, as a result, the introduction below is primarily of the GPS system.

1.2 GPS Navigation System

The GPS navigation system was developed by the U.S. Air Force space agency. It is capable of providing high precision three dimensional position and speed data as well as accurate time. It provides 24 hour service every day to the entire world. The satellite constellation network is composed of 24 satellites. Six orbital planes and the equatorial plane intersect each other forming angles of 55°. Each satellite uses the same frequency to transmit. Use is made of data codes with the addition of dummy codes to carry out BPSK modulation on carrier frequencies. Data code rate is 50bit/s. Dummy code rate is 1.023MHz. The repetition sequence is a code length of 1023 code bits. Code period is 1ms. Standard service operating frequency is 1575.42MHz. Civilian groups of the world can all use it without being subject to limitations. Besides the signals described above, military equipment makes use of dual frequency precision positioning services. Moreover, use is made of very long coding sequences in order to guarantee transmission security. The second frequency is used to eliminate the influence of the ionosphere in order to improve accuracy. /2

As far as the satellite data transmission rate of 50bit/s is concerned, telecommunications include configuration soundness, satellite identification, ephereris data (EPH), satellite clock calibrations, ionospheric correction parameters, as well as a good number of other data. Users measure pseudoranges (electric wave propagation delays) associated with more than 4 satellites, demodulating satellite ephereris among satellite transmission data, thereby fixing user position and time. Besides coding and

tracking, pseudorange measurements are also capable of use in realizing locked phase carrier waves. Receivers are normally divided into two types--single channel and multichannel. After the establishment of the GPS net, the U.S. Defense Department has opted for the use of selective availability (SA) plans, causing standard service positioning accuracies to be limited to within approximately 100m (two dimensional root mean square value). GPS receivers are capable of all weather service everywhere in the world. If there is a requirement for higher precisions, differential GPS supplies an economical and feasible method.

2 DESCRIPTION OF DIFFERENTIAL GPS

2.1 General Situation

During differential GPS operations, it is possible to supply 5-10m accuracies for moving navigational users. With regard to stationary users, precisions can be better than 3m. The concept of differential GPS is similar to differential Luolan (phonetic) C and differential Omega methods. One datum receiver unit is installed at an already known measured point. Comparisons are carried out between the already known position and the position fixed by GPS. It is possible to arrive at correction quantities. These correction quantities are then taken and broadcast to users in the vicinity. Subscribers then use these correction quantities in order to improve their position resolutions.

Differential technologies make use of datum station receivers and user receivers having a common view of the satellite constellation. The correlations associated with receiving satellite signals (that is, signal propagation paths coming from satellites at basically the same times being fundamentally the same, and having a common view of the same satellites, therefore, satellite ephereris errors, satellite clock errors, the influences of SA plans, and so on, are all basically the same) make it possible to supply for GPS users real time positioning precision. This is appropriate for use in situations where deviation error sources given rise to outside receivers are comparatively large. These error sources are as follows.

(1) Selective availability errors--for security reasons, artificial errors are introduced into satellites, leading to pseudorange errors of approximately 30m (1σ values). Precision positioning users have code keys to undo these errors--capable of completely eliminating them.

(2) Ionosphere delay errors--signal propagation delays can reach 20-30m in the day time and 3-6m at night. Use is made of dual frequency operating methods which are capable of very, very greatly eliminating these influences.

(3) Troposphere delays--signal propagation delays given rise to by the lower atmosphere can reach 30m with regard to low elevation angle satellite delays. The errors in question are basically constant. In conjunction with

this, it is possible to simulate changes in refractive indices. With respect to low elevation angle satellites, it is possible to give rise to 1-3m signal delay error values.

(4) Ephereris errors--the difference in values between actual satellite positions and positions inferred from satellite orbits. This quantity normally does not exceed 3m.

(5) Satellite clock errors--the difference in values between satellite clock time and times predicted by the satellite.

It is only necessary for user stations and datum stations to act on the same satellite data, and differential operations are capable of completely compensating for satellite clock error. With regard to ephereris error--if it is not too large--differential operations are also capable of carrying out similar compensation. Selective availability is a type of correlative noise process associated with a few minutes of correlation time. The effects are similar to slow changes associated with clock drift. It is also possible to use differential operations to carry out compensation. Influences of the ionosphere on radio signals and the numbers of free electrons along signal paths are in proportion. With regard to users in the vicinity of datum stations, the various signals reaching satellites are normally very close. Errors are almost completely compensated for. When distances between users and datum stations increase, the delays given rise to by nonuniformities going through different ionosphere and troposphere atmospheres to satellites become more different. When a certain level is reached, a differential GPS measurement error is then formed. The larger user and datum station distances are, the larger difference values are. A differential GPS schematic is drawn out in Fig.1. A differential GPS datum station line and block chart is shown in Fig.2.

2.2 Equipment Profiles and Design Requirements:

/3

Differential operations are to put a datum station GPS receiver at an already known location, to precisely determine the slant range correction quantities to satellites, and to broadcast these to the serviced users. In this way, it is possible to eliminate all common receiver deviations and errors, thereby improving positioning accuracy. The positioning precisions are only subject to user receiver noise internal channel deviations and errors as well as the limitations of datum station positioning inaccuracies. However, these limitations are capable of being improved through the carrying out of wave filtration with regard to receiver noise and precise geodetic services (see Fig.1). The methods we opt for the use of are not taking correction quantities and using them in subscriber calculations of position quantities. They are, however, used in user pseudorange calculation quantities. The reason is that, as far as users and datum stations are concerned, certain causes have a possibility of making scalar quantities associated with satellites they are tracking as well as

quantities associated with satellites they are tracking as well as satellite designations be different. If, among multiple satellites that they are respectively receiving, it is only desired to have three or more than three be the same, and the others all not be common satellites, it is also possible to realize differential positioning. Moreover, positioning accuracies are clearly improved. However, satellites commonly viewed by datum stations and user receivers cannot be less than 3. Otherwise, they cannot satisfy the conditions for common viewing, and positioning errors will be very great.

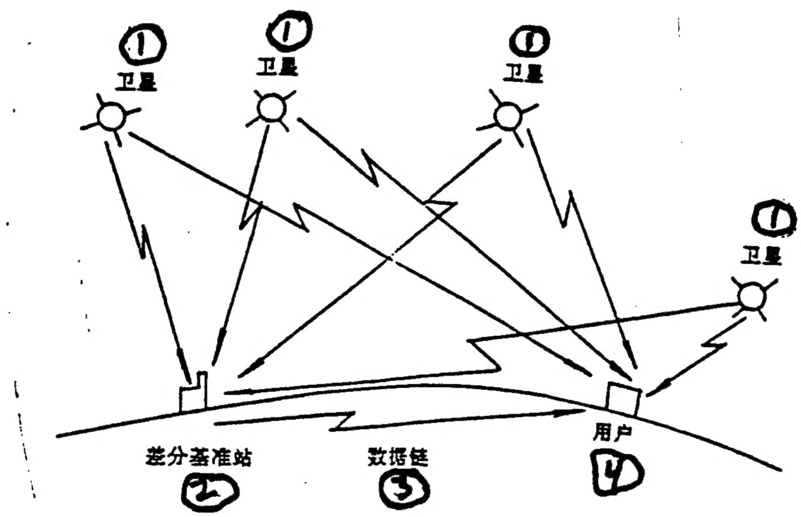

Fig.1 Differential GPS Schematic

Key: (1) Satellite (2) Differential Datum Station (3) Data Link (4) User

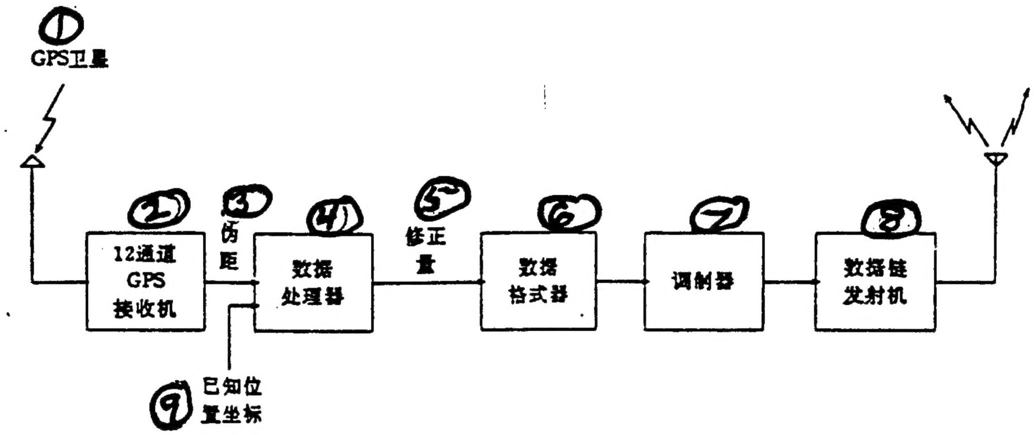

Fig.2 Differential GPS Datum Line and Block Chart

Key: (1) GPS Satellite (2) 12 Channel GPS Receiver (3) Pseudorange (4) Data Processor (5) Correction Quantity (6) Data Format Device (7) Modulator (8) Data Link Transmitter (9) Coordinate of Already Known Location

Taking pseudorange correction quantities associated with all the satellites visible to datum stations and broadcasting them, user receivers then use differential methods to precisely specify their own positions.

2.3 Datum Stations

As is shown in Fig.2, differential GPS datum stations are composed of GPS receivers that carry antennas, data processors, data transmitters that carry antennas, as well as connection equipment. After antennas are fitted, their phase center locations should be measured. When they and data link antennas are installed, consideration should be given to surrounding buildings and terrain, achieving as little masking as possible.

Datum station receivers are multichannel ones. A channel corresponds to one visible satellite. At the present time, there are 21 official satellites aloft. Besides these, there are 3 back up satellites. Over 99% of the time, visible satellites do not exceed 12. As a result, consideration should be given to the use of 12 channel receivers.

When satellites come up, their signals can then be received by one of the receiver channels. When signal to noise ratios reach an appropriate level, slant range measurement quantities are sufficiently stable, and suitable data has already been acquired,

datum stations then broadcast the correction quantities associated with that satellite. So long as satellite signals are sound, transmissions continue to be carried out right up until the satellite in question goes down and service signals disappear, when they stop. /4

Datum station receivers carry out carrier wave phase tracking and code tracking. Code tracking skips the local code phase, going right on until it makes a correlation between it and satellite signal code phases, in conjunction with that, tracking them. As far as carrier waves are concerned, use should be made of lock phase technology to carry out synchronicity tracking. Due to satellite motions, it is possible to make carrier wave frequencies produce Doppler frequency shifts. With satellite positions already precisely known, Doppler frequency shifts and time delay changes can be completely predicted. It is possible--going through time periods of several tens of seconds--to carry out smoothing in order to reduce measurement indeterminacies. Due to the fact that datum station positions are capable of being precisely measured, as a result, it is then possible to fix slant range errors. In slant range velocities, if one takes out satellite velocity influences, they should almost be 0. If they are not zero, then, it is possible to believe them to be introduced SA errors. Accurately taking out satellite motion influences and using optimum wave filter processing to measure data, it is possible to provide slant range and slant range velocity error predictions to use in the next electrical message broadcast.

Satellites themselves are capable of supplying reliability and precision indices associated with transmission signals. Datum stations are also capable of carrying out detection with regard to signals. Comparisons are carried out using measurement slant ranges and slant ranges derived from satellite positions (derived from ephereris tables). As a result, it is almost impossible for datum stations to transmit inaccurate signals. The U.S. GPS control station has a possibility, before loading a new soundness message, that signals will drift off stipulated values. Datum stations are capable of immediately detecting this configuration, altering satellite soundness bits and sending out each correction quantity following that. Datum stations are also capable of detecting large ranges of changes given rise to by SA.

2.4 User Equipment

User equipment includes receivers that carry antennas, data processors, data link receivers that carry antennas, as well as connection equipment. A line and block chart for user equipment is shown in Fig.3. Data processors take datum station correction quantities and use them in receiver pseudorange measurements.

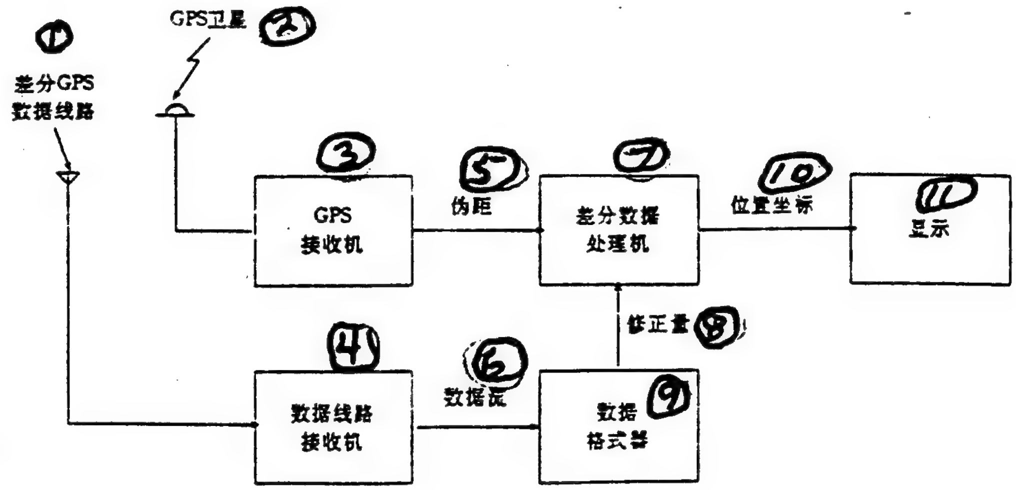

Fig.3 User Equipment Line and Block Chart

Key: (1) Differential GPS Data Line (2) GPS Satellite (3) GPS Receiver (4) Data Line Receiver (5) Pseudorange (6) Data Flow (7) Differential Data Processor (8) Correction Quantity (9) Data Format Device (10) Position Coordinates (11) Display

As far as receivers are concerned, normally, use is made of multichannel receivers. They are capable of carrying out reception with regard to all satellite signals. In conjunction with this, they are capable of carrying out optimum combinations and are also able to make use of precision measurements of altitude in order to carry out optimum combinations.

User receivers take datum station correction quantities with regard to each satellite and take them out from among pseudorange quantities. Correction quantities are derived from slant ranges and slant range velocities in accordance with calculations associated with the formula below.

$$\delta PR(t) = \delta PR_o + \delta PR(t-t_o)$$

In the equation, $\delta PR(t)$ is the correction quantity used.
δPR_o is datum station slant range correction quantity relating to satellites.
1 is datum station slant range velocity correction quantity.
t_o is correction quantity calibration time.
t is pseudorange measurement time. /5

Data links are capable of taking datum station correction

quantities and transmitting them to user receivers. These should guarantee being capable of reliable communications and continuous transmissions. Speeds are generally not lower than 50 bauds. At receiver terminals, there is buffering in order to facilitate data going through receiver I/O ports. From buffers, they are sent to storage devices. The data link line and block chart is shown in Fig.4.

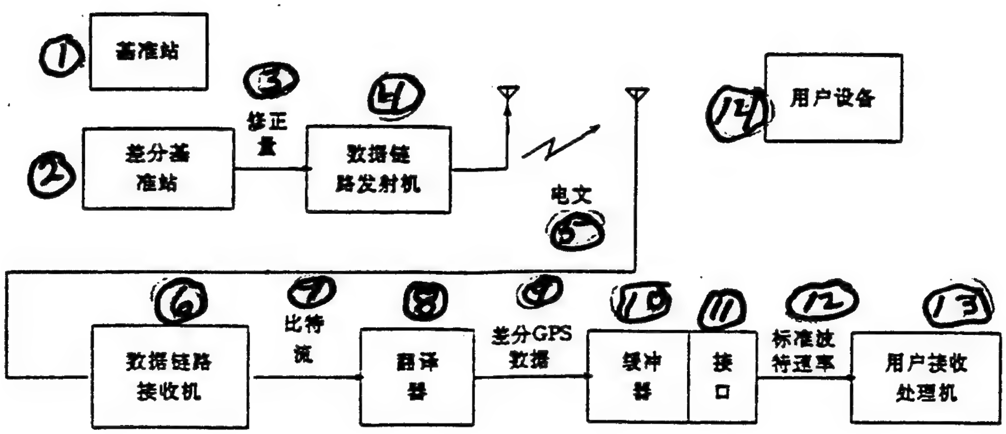

Fig.4 Data Link Line and Block Chart

Key: (1) Datum Station (2) Differential Datum Station (3) Correction Quantity (4) Data Link Transmitter (5) Message (6) Data Link Receiver (7) Bit Flow (8) Translation Device (9) Differential GPS Data (10) Buffer (11) Connection (12) Standard Baud Speed (13) User Reception Processor

For the sake of propagating the commonly beneficial services associated with differential GPS, its data links should be open links of standard design. However, considering economic benefits, it is also possible to take data and compose it into forms of secret code, conducting fee for service.

A special tool of differential GPS is pseudo satellites. The advantages associated with the use of pseudo satellites in differential systems are very numerous. Owing to limits on the scope of this article, it does not introduce them. Interested readers can refer to relevant materials.

Communication frequency bands associated with differential GPS are capable of making use of frequency bands which are distributed in their utilization to radio navigation or positioning.

Due to the fact that differential GPS data speeds are very low (50-100 bit/s), serial ports are, therefore, utilized. The electrical connections between communications systems and GPS user equipment are standard RS-422 full two way digital connections.

They are compatible with standard telecommunications modulator/demodulator devices. In this way, user equipment is capable of receiving data associated with speeds of between 300-9600 bauds coming from communications systems.

Opting for the use of differential technology, it is possible to improve GPS positioning precision. Test data associated with the Trinble company, the Magnavox company, and so on, clearly show that GPS user receivers 200-300km from differential datum stations have positioning precisions reaching 3-5m (root mean square value). With regard to users at 1000km or more, GPS receiver positioning precisions still only have some theoretical analysis. In order to facilitate having a better grasp on satisfying the requirements of Chinese survey ships with regard to positioning precisions as well as index requirements of civilian departments with respect to long range differential GPS technology, we carried out medium and long range differential GPS tests. In order to save on outlays, communications equipment did not participate in these tests.

3 DIFFERENTIAL TESTS

As is shown in Fig.1, a 10 channel 4000SR receiver is placed on a datum point whose geodetic coordinates and altitude are already known. Use is made of portable type personal computers to record ephereris, pseudoranges, Doppler frequencies, and so on, associated with satellites visible at the locations in question with angles of elevation of more than 10°. Application is made of long range GPS pseudorange differential software which we have developed to calculate out pseudorange GPS calibration information. In conjunction with that, it is stored on floppy disks to await use. Users make use of 5 channel 4000SX receivers. During static tests, the devices in question are positioned at an already known location on the roof of the No.2 scientific research building of the electronics ministry's Xian Institute 20. During mobile tests, these systems are placed inside a small bread truck. The vehicle drives along the western section of the Xian city Nanerhuanlu. In conjunction with this, the instants when the vehicle passes through already known points are recorded. User receivers--in accordance with requirements associated with satellite forecast results--use portable personal receivers to record ephereris, pseudoranges, as well as Doppler frequencies, and so on, for 4-5 satellites visible at the locations in question and commonly viewed by datum stations. This information is stored on floppy disks to await use.

As far as datum station differential information is concerned, it is sent to user stations through postal means. Application is made of long range GPS pseudorange differential software. Transferring datum station differential calibration data and user data, such information as user locations and movements speeds are calculated out. /6

In September 1994, a datum station was set up at an already known location on the roof of the telemetry and communications institute laboratory building. In October 1994, a datum station was set up at an already known location at the No.2 position of the

Jinxi navy base. The datum station and user station program flow charts are as respectively shown in Fig.5 and Fig.6.

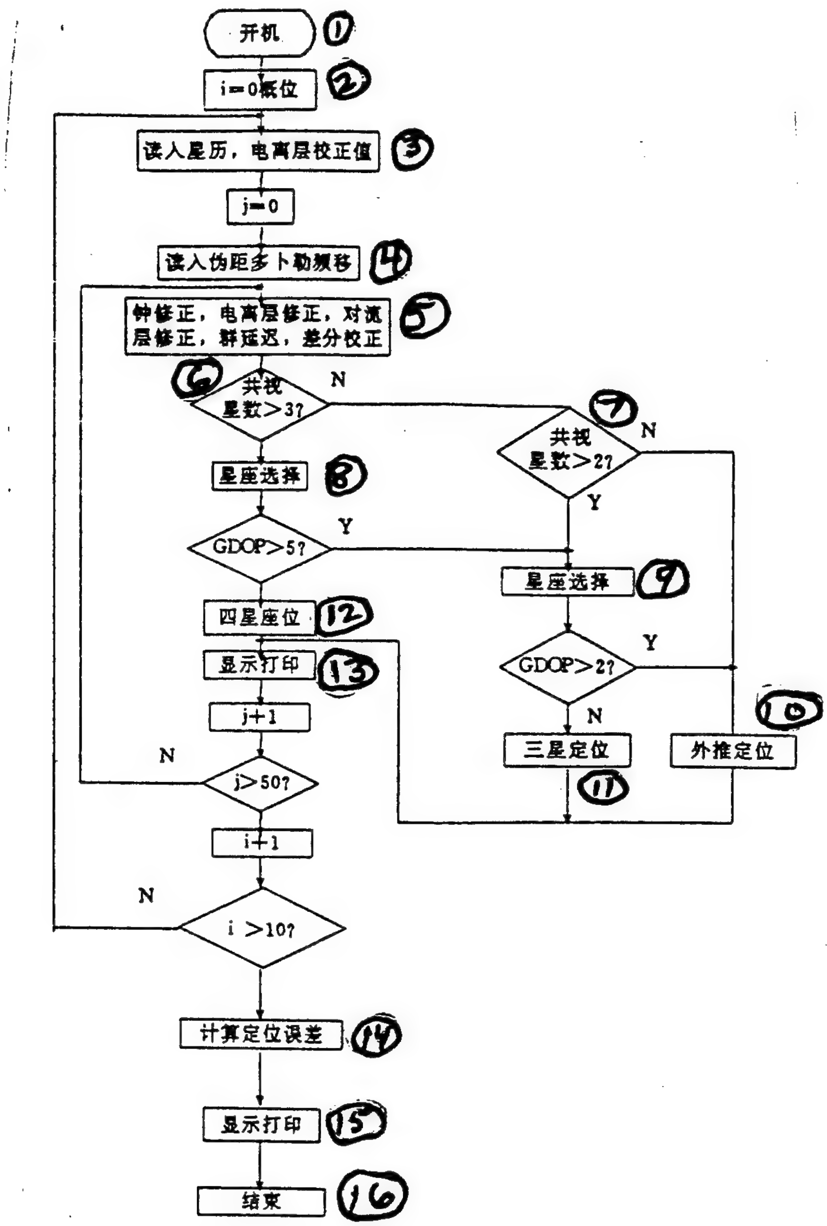

Fig.5 Long Range GPS Pseudorange Differential User Station Program Flow Chart

Key: (1) Turn On (2) i=0 Probability Value (3) Read In Ephereris and Ionosphere Calibration Values (4) Read In Pseudorange Doppler Frequency Shift (5) Clock Correction, Ionosphere Correction, Troposphere Correction, Group Delay, Differential Calibration (6) Commonly Viewed Satellite Number > 3? (7) Commonly Viewed Satellite Number > 2? (8) Constellation Selection (9) Constellation Selection (10) Extrapolated Position (11) Three Satellite Position (12) Four Satellite Constellation Position (13) Display Print Out (14) Computational Positioning Error (15) Display Print Out (16) End

Relevant data are set out in Table 1, Table 2, and Table 3 (see the end of the article).

From test results, it can be seen that, as far as a distance of 300km between Xian and Luoyang is concerned, static C/A code pseudorange differential horizontal position error $\sigma<1m$. rms<3m. With regard to a distance of 1300km between Xian and Jinxi, static C/A code pseudorange differential horizontal position error $\sigma<3m$. rms<10m. Dynamic C/A code pseudorange position errors from Xian to Jinxi are as follows. Point 1 $\sigma_x<2.8m$, $\sigma_y<2.9m$. Point 2 $\sigma_x<2.5m$, $\sigma_y<4.6m$. Point 3 $\sigma_x<3m$, $\sigma_y<3.6m$. /7

From the description above and test results, it is possible to see that the advantages of differential GPS are many. Positioning accuracies are high. Coverage ranges are broad. Equipment is also very simple--only requiring one datum station and appropriate data links. Continuous service is possible. Effective altitude correction speeds cause differential GPS to be capable of supplying real time, high precision positioning data. As a result, it possesses broad applications.

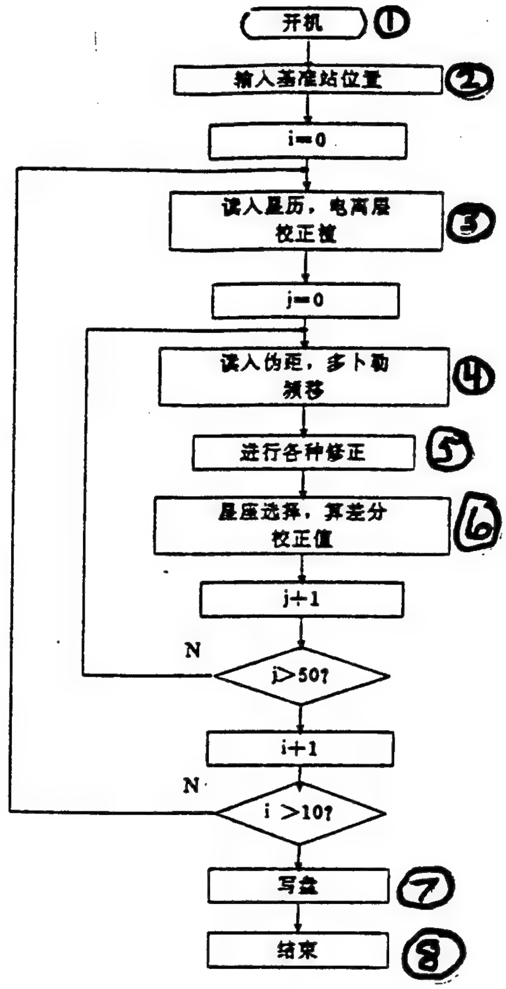

Fig.6 Long Range GPS Pseudorange Differential Datum Station Program Flow Chart

Key: (1) Turn On (2) Input Datum Station Position (3) Read In Ephereris and Ionospheric Calibration Values (4) Read In Pseudorange and Doppler Frequency Shift (5) Carry Out Various Types of Corrections (6) Select Constellation and Calculate Differential Calibration Values (7) Write to Disk (8) End

4 DIFFERENTIAL GPS APPLICATIONS

4.1 Navigational Applications

Maritime Navigational Applications. A number of harbor navigation routes are narrow. There is a requirement for functions to fix the positions of ships to within accuracies of 3-5m. Lighthouse management demands functions with precisions of 5m.

Aerial Navigation Applications. Precision aircraft landings require high accuracy vertical direction guidance with precisions better than 5m as well as lateral direction guidance better than 10m.

Land navigation is a realm of research that is just now in the process of being developed. Vehicular transport security services combine mobile communications and make use of radios to transmit to motorcade/vehicle unit control centers in order to increase national security capabilities in cities and the countryside. Buses, trucks, and taxis can all make use of this technology. /8

4.2 Positioning Applications

Maritime Positioning Applications. As far as differential GPS maritime applications are concerned, it is possible to use it to explore the ocean bottom and find crude oil and natural gas. It is used in order to accurately fix the precise locations of ships. With regard to China's Yuanwang survey ships, it is also possible to apply this technology to carrying out any required fixing of ship positions to precisions < 10m.

Ocean current surveys requiring location positioning precisions within 30m as well as maritime geology and geophysical explorations are involved.

Hyrdrological buoy positioning, buoy location detection, cable laying and maintenance, as well as commercial fishing are relevant.

Land Positioning Applications. Geodetic markers are often plowed flat by bulldozers--purposely destroying them or making their use difficult. At these times, it is possible to make use of differential GPS positioning. As far as highway surveying and boundary line surveying are concerned, the speed of using differential GPS is fast, and it simplifies highway equipment.

It is obvious to see that the range of uses associated with differential GPS is very broad. It is also possible to discover new applications in the fields of commercial or scientific groups. It is possible to say with certainty that differential GPS will produce revolutions with regard to a number of important operations. As a result, it is now necessary to exert great efforts in research and development in order to promote the development of the Chinese economy as well as strengthening national defense forces.

5 PROPOSALS FOR THE CONSTRUCTION OF CHINESE DIFFERENTIAL NETWORKS

In order to construct China's differential GPS network--on the basis of the Chinese national situation--we believe that use should first be made of radio signal beacon subcarrier waves to broadcast differential GPS data as well as to internet GPS and maritime satellites to issue differential GPS signals.

5.1 Radio Beacon Subcarrier Wave Broadcasting of Differential GPS Data

As far as the independent setting up of area differential broadcasting systems is concerned, it is not only necessary to increase shore stations and user equipment. Moreover, construction costs will also increase. As a result, consideration is given to making use of China's currently existing radio direction beacons to transmit differential GPS correction data--not only saving on equipment, but making costs also not too large. China's maritime shoreline is something over ten thousand kilometers. 16 radio directional transmitting units have already been set up. It is only necessary to take GPS differential datum station correction data and modulate subcarrier waves in the radio direction beacons to transmit them out. Maritime users are then able to use GPS receivers having differential functions to carry out precision positioning with accuracies better than 10m. The key to this technology is that it cannot influence the direction finding precision of directional beacons. Schematics associated with the plan are shown in Fig.7 and Fig.8.

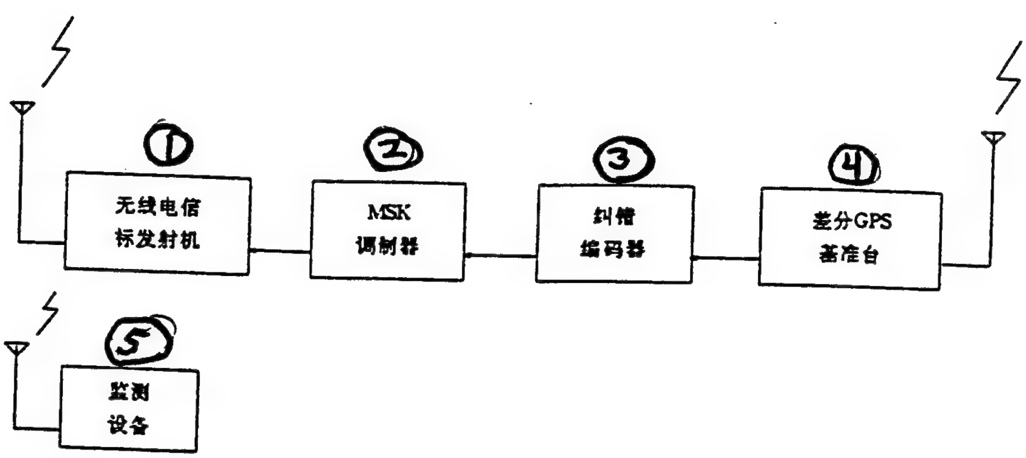

Fig.7 GPS Differential Datum Station Equipment Line and Block Chart

Key: (1) Radio Beacon Transmitter (2) MSK Modulator (3) Fault Correction Encoding Device (4) Differential GPS Datum Station (5) Monitoring Equipment

5.2 GPS and Maritime Satellite Interneted Issuing of Differential GPS Signals /9

The international maritime satellites INMARSAT are a satellite communications system which was jointly invested in and developed by various member nations of the International Maritime Organization. It is primarily used in communications of different ocean going vessels at sea and rescue during mishaps. China is a member state of the organization in question. In conjunction with this, it sends representatives to take a seat on the board of trustees of this organization. We should make full use of maritime satellite resources. The International Maritime Organization--in consideration of the benefits to various member states and the development of this system itself--plans, in 1995, to make use of a new generation of INMARSAT-2 model satellites repeating GPS broad region differential correction data, making it into a broad region differential GPS satellite data transmission center. At the same time, there are plans to add useful load to INMARSAT-3 model satellites--allowing them to broadcast to users the same L.1 C/A code navigation signals as those associated with GPS satellites. This is also nothing else than to say that INMARSAT-3 model satellites are capable of acting in the role of a GPS satellite. We should--in contact with the International Maritime Satellite Organization--assume responsibility for developing and making use of India's maritime satellites aloft over the oceans--using them in order to broadcast GPS system broad region differential correction data. For the sake of broad GPS user services in this area, a further step is taken to develop INMARSAT-3 model satellite effective loads--making them possess the functions of GPS satellites.

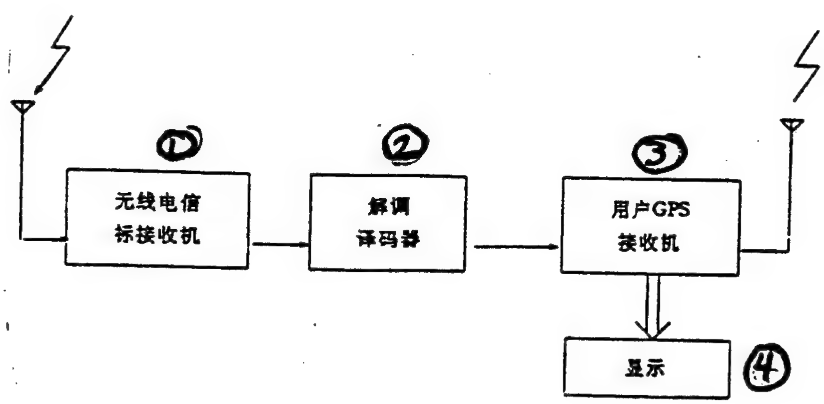

Fig.8 User Equipment Line and Block Chart (1) Radio Beacon Receiver (2) Demodulation Decoder Device (3) User GPS Receiver (4) Display

As far as GPS and maritime satellite interneted issuing of differential GPS signals or interneting of various surface differential datum stations are concerned, after going through processing, users are given what are called broad area differentials through maritime satellite broadcasts. The principles associated with broad area differential GPS positioning are the same as general differential GPS positioning principles. Their objective is to realize real time, high precision positioning associated with carrier bodies--effectively overcoming the influences on accuracies of the U.S. opting for the use of SA measures on GPS. It is only by the broadcast of differential correction data to users through satellites that the coverage ranges of differential systems are then, in this way, very, very greatly expanded. Taking datum stations and dividing them into main stations and monitoring stations--by main stations collecting signals sent from their various peripheral differential monitoring stations and by broadcasting them, after going through processing, to broad GPS users in the areas in question through satellites, users extract differential correction data which is the most beneficial to improving their positioning accuracies on the basis of rough locations (probable positions). In this way, making use of component networks is more advantageous to improving real time positioning precisions for differential GPS users. Utilizing transponders on international maritime satellites, their communications channels are then leased, broadcasting to the many GPS users in the areas in question differential correction data. First of all, it is necessary to develop system tests--that is, study their demonstration systems, waiting for the success of system tests. Then, engineering and construction is carried out. At this time, it is necessary to construct stations from a unified national plan. It is also possible to combine component nets with adjacent countries or even various nations of the world. As far as building differential datum networks is concerned, additional construction is done of maritime satellite shore stations as well as the seriated user equipment which they require. System coverage ranges achieve at least coverage of the range of national territory, extending outward 500-1000km. Positioning accuracy is 5-10m(rms).

6 BRIEF SUMMARY

At the present time, the units which are studying differential GPS domestically are not numerous. The content is also comparatively complicated. This article is only able to carry out a number of descriptions from the main perspectives. Because the level is very limited, as far as inadequacies are concerned, it is requested that experts criticize and point out mistakes. /10

Table 1 Luoyang--Xian Fixed Point Pseudorange Differential Position Errors

Sequence No.	Distance (m)	rms (m)	Statistical Count
1	0.92	1.97	399
2	1.29	2.15	487
3	0.75	1.72	496
4	0.79	3.55	499
5	2.4	3.29	488
6	0.62	0.85	492
7	0.5	0.66	493
8	1.01	3.17	492
9	0.91	2.27	493
10	0.86	1.74	496
11	0.82	1.55	490
12	0.72	1.41	491
13	0.84	1.74	488
14	0.9	2.78	497
15	0.75	3.02	349
16	0.74	1.54	497
17	0.78	3.06	492
18	0.87	1.91	491
19	1.08	2.27	449
20	1.51	2.32	493
21	0.54	3.16	349

From this table, it is possible to see that, horizontal positioning errors $\sigma < 1$m. Root mean square errors rms < 3m.

Table 2 Jinxi--Xian Fixed Point Pseudorange Differential Position Errors

Sequence No.	Distance (m)	rms (m)	Statistical Count
1	1.07	7.88	499
2	2.65	11.33	499
3	1.36	7.76	498
4	2.62	8.81	496
5	1.04	9.92	492
6	2.3	8.72	499
7	1.23	5.45	493
8	3.8	10.43	494
9	1.32	9.73	499
10	2.21	4.54	493
11	3.03	6.70	498
12	2.46	7.53	496
13	3.03	6.76	496
14	2.7	8.50	357
15	3.13	6.78	493
16	1.16	9.53	483
17	3.61	7.05	490

From this table, it is possible to see that horizontal positioning errors $\sigma < 3m$. Root mean square errors rms < 10m.

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Table 3 Jinxi--Xian Moving Pseudorange Differential Position Errors (Gauss Coordinate System) (1) Point No.1 (Touring School) Moving Differential Error (2) Surveyed Position Value (3) Sequence No. (4) Average Value (5) Point No.2 (Taoyuan Lake) Moving Differential Error (6) Point No.3 (Qiaobei) Moving Differential Error

第一点(旅游学校)动态差分误差 1			
	3 序 号	X (km)	Y (km)
2 测量定位值	1	3792.518	19306.732
	2	3792.514	19306.731
	3	3792.512	19306.733
	4	3792.520	19306.735
	5	3792.516	19306.737
	6	3792.519	19306.734
	7	3792.518	19306.740
4 平均值		3792.518	19306.734
σ		2.92×10^{-3}	2.87×10^{-3}
第二点(桃园湖)动态差分误差 5			
	3 序 号	X (km)	Y (km)
2 测量定位值	1	3792.919	19306.024
	2	3792.916	19306.030
	3	3792.922	19306.030
	4	3792.920	19306.031
	5	3792.916	19306.030
	6	3792.914	19306.040
	7	3792.918	19306.035
4 平均值		3792.9178	19306.031
σ		2.53×10^{-3}	4.59×10^{-3}
第三点(桥北)动态差分误差 6			
	3 序 号	X (km)	Y (km)
2 测量定位值	1	3792.547	19305.124
	2	3792.541	19305.125
	3	3792.544	19305.128
	4	3792.537	19305.131
	5	3792.538	19305.133
	6	3792.535	19305.733
4 平均值		3793.539	19305.129
σ		3.095×10^{-3}	3.605×10^{-3}

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